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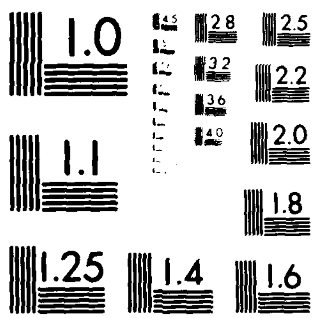

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Long-Term Intensity Decrease in the 8-25 MeV Proton Fluxes at Low L Values

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A five year continuous observation, 1963 to 1968, of the 8-25 MeV proton population, at $L < 2.0$, had shown a monotonic decrease in this population. We have observed the same proton population from 1970 to 1976, using experiments flown on several USAF satellites (72-1. S3-2, S3-3). These data together with published data from the DIAL satellite show that the

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20. decreases in the proton fluxes first observed from 1963 to 1968 have continued unabated, at least until August 1976, and with the same original mean lives. The proton flux at $L=1.35$ decayed over the 13-year period (1963-1976) with a mean life, τ, of 5.7 ± 0.5 years. At $L=1.90$, τ was 4.55 ± 0.16 years. However, the proton flux at $L=1.20$, which had first been reported as constant, started decreasing $\sim$ 1970 to 1976 with $\tau = 3.07 \pm 0.25$ years. Possible explanations for this phenomenon can be divided into the two categories of natural and artificial effects. We reviewed these different effects and conclude that most likely we are seeing the decay of the high energy protons redistributed by the "Starfish" high altitude nuclear explosion.

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LONG-TERM INTENSITY DECREASE IN THE 8-25 MeV PROTON FLUXES AT LOW L VALUES

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ABSTRACT

A five year continuous observation, 1963 to 1968, of the 8-25 MeV proton population, at $L < 2.0$, had shown a monotonic decrease in this population. We have observed the same proton population from 1970 to 1976, using experiments flown on several USAF satellites (72-1, S3-2, S3-3). These data together with published data from the DIAL satellite show that the decreases in the proton fluxes first observed from 1963 to 1968 have continued unabated, at least until August 1976, and with the same original mean lives. The proton flux at $L = 1.35$ decayed over the 13-year period (1963-1976) with a mean life, τ, of 5.7 ± 0.5 years. At $L = 1.90$, τ was 4.55 ± 0.16 years. However, the proton flux at $L = 1.20$, which had first been reported as constant, started decreasing $\sim$ 1970 to 1976 with $\tau = 3.07 \pm 0.25$ years. Possible explanations for this phenomenon can be divided into the two categories of natural and artificial effects. We reviewed these different effects and conclude that most likely we are seeing the decay of the high energy protons redistributed by the "Starfish" high altitude nuclear explosion.

INTRODUCTION

The long-term monitoring of the trapped particle fluxes in the Earth's magnetosphere should be of considerable help in the understanding of its dynamics. However, the long-term behavior of the trapped protons is far from being understood, and several outstanding questions remain unexplained, among which is the apparent decrease of the proton fluxes, at low L values in the 8-25 MeV energy range, observed over a period of five years (1964-1968) by Bostrom et al., (1971).

In this paper, we report the results of several measurements of 8.5-25 MeV proton fluxes made over several time periods of approximately six months long each, between 1972 and 1976. Our results indicate that the decrease in the fluxes first observed by Bostrom et al. have continued unabated, at least until August 1976.

INSTRUMENTATION

Our data were obtained using instrumentation flown on board the polar orbiting Air Force satellites 72-1, S3-2, and S3-3. The relevant orbit parameters for these satellites are shown in Table I.

A solid state particle identifier telescope was flown on 72-1. For a description of this instrument, the reader should refer to papers by Morel et al., (1972), and Filz et al., (1974). Two identical solid state proton telescopes were used on S3-2 and S3-3, and these have been described in another paper (Morel et al., 1974).

DATA ANALYSIS

The data obtained with the proton telescope on 72-1 have been reported previously (Holeman and Filz, 1975). The final data tabulations

gave the directional and omnidirectional fluxes sorted in various earth radii, L, groupings and 100 km H_{min} intervals. The magnetic field model used in the analysis was IGRIF 1965 model. The relevant magnetic field for the year of a particular series of observations was then calculated using the secular change coefficient. The 72-1 data covering an L region from 1.14 to 3.40 earth radii, and H_{min} of 100 to 700 kms were given as a function of pitch angle for each of the 5 energy channels (5-45 MeV). Preliminary data analysis of the S3-2 and S3-3 experiments were also reported (Holeman et al., 1978). These data have now been analyzed in a final form and will be published shortly (Holeman et al., 1981). The S3-2 and S3-3 data gave an excellent coverage of the region in "L-H_{min}" space including $1.16 \le L \le 3.0$, $240 \le H_{min} \le 1400$ km; and $1.20 \le L \le 3.80$, $240 \le H_{min} \le 6900$ km respectively. H_{min} is defined as follows: For a given set of B, L values, B-L iso-contours are drawn in the northern and southern hemispheres. The minimum altitude for each set of these iso-contours is called H_{min}. This minimum value occurs in the southern hemisphere, in the South Atlantic Anomaly, due to the offset of the Earth's dipole. The energy range covered was from 5 to 100 MeV, in 5 energy channels.

The data from 72-1 were recorded over a six month period starting October 1972 and ending May 1973. During this time period no significant intensity fluctuations were observed in the regions of interest. The data from S3-2 consisted of 186 orbits from December 1975 to March 1976, and for S3-3 we analyzed 383 orbits from July 1976 until January 1977. The data from S3-3 used in the present analysis were for the July - August 1976 period. In addition, we used selected data from the German satellite DIAL which were recently published (Fischer et al., 1977). These data were recorded in April 1970.

EXPERIMENTAL RESULTS

The original data recorded by the satellite 1963-38C spanned a time period starting October 1963 and ending January 1969. During this period, the 8.2-25 MeV proton fluxes were monitored at L values between 1.20 and 2.60. Between $1.35 \leq L \leq 2.20$, the proton fluxes were observed to decrease monotonically as a function of time.

We selected data, taken with our 3 experiments on board the 3 Air Force satellites, at the same B and L positions. These coordinates are listed in Table II together with the mirroring proton fluxes observed (protons/cm^2-sec-ster-MeV).

For the instruments on-board S3-2 and S3-3, the energy interval under consideration corresponded to channels 2 and 3 (8.0-13 and 13-25 MeV, respectively) of the 5-energy channel spectrometer of each instrument. The closest channels of the spectrometer on 72-1 which coincided with the energy range of interest, were channels 2, 3 and 4 (7.0-12.2, 12.2-18.2 and 18.2-28 MeV). We interpolated the data to cover the energy range 8-25 MeV, and took into account these corrections as part of the uncertainties in the data points thus calculated. Similar corrections were applied to the DIAL satellite data.

The values for the 1963-38C were taken from Figure 6 of Bostrom et al., (1971). The uncertainties were estimated from the scattering of the data points for the curve at L=1.35. We assigned the same percentage uncertainties to the data points at L=1.20 and L=1.90.

The data points of April 1970, recorded by the DIAL satellite, were taken from Figures 5 and 6 in the paper by Fischer et al., (1977). Our interpolation of the data to cover the 8-25 MeV range together with the scattering of the data at each of the particular (B,L)

coordinate points, determined the uncertainties assigned to these data.

Figure 1 shows the directional proton intensities ($J_\perp$) in protons/ cm^2-sec-ster-MeV, versus time, from January 1964 until August 1976, starting with the five-year continuous measurements of 1963-38C represented by the heavy lines.

In order to calculate the mean lives of the proton flux decreases, we performed a weighted least-square fit to a simple exponential, $J_t = J_o \exp(-t/\tau)$. As far as the 1963-38C data were concerned, we took the intensities at the beginning and end of the measurement period. At L= 1.20, this satellite measured a constant flux during the 5-year measurement period. However, since our data clearly show a steady decrease in the proton flux on that field line starting somewhere after January 1969, we only consider in the fit the flux intensity at that time together with the three other data points recorded between 1970 and 1976.

Table III shows the resulting mean lives calculated from the data. The mean lives at L=1.35 and 1.90, as calculated with the data available from 1964 to 1976, are in very good agreement with the original mean lives as measured by 1968-38C satellite. Our data at L=1.20 clearly shows a decrease on that field line, in contrast with the constant flux measured during 1964-1968 period.

DISCUSSION

Possible explanations for the observed behavior of the 8-25 MeV trapped proton fluxes can be divided into the two categories of natural and artificial phenomena. But the empirical data indicate that during our period of observation (1964-1976) the proton fluxes had to

exceed those which would otherwise have been balanced by natural sources over more than one 11-year solar cycle.

For this reason, any explanation of a natural origin of the phenomenon for injection requires large perturbation event(s) not seen in the present 11-year solar cycle. McIlwain (1965) has observed changes in proton fluxes at higher L values during major magnetic storms. In particular, variations of the 2.2-8.2 MeV proton fluxes were observed during the spectacular May 26, 1967 magnetic storm by Bostrom et al., (1971). However, these same authors saw no variation of the 8.2-25 MeV proton fluxes at $L \leq 2$.

The order-of-magnitude decay of the 8-25 MeV proton fluxes seen here between 1964 and 1976 at L = 1.20, 1.35, and 1.90 suggests that any increases caused by an earlier magnetic storm (prior to 1964) must have been very large indeed. However, the rather exceptionally large May 1967 event was observed to have no effect whatsoever at these L values (Bostrom et al., 1971). While storms comparable to this May 1967 event (Dst = -418γ) were seen in 1958 and 1959 (Dst = -422γ and -436γ respectively), no significant larger storms were seen during the last two solar cycles. No magnetic storms with Kp > 9- were observed from 1947 through 1956, (Cage and Zawalick, 1972; Mayaud and Romana, 1977), and the 4 September 1957 storm was not as large as the May 1967 storm judging by the Dst measurements.

Several times during the previous and present centuries, outstanding tropical aurorae have been observed, coinciding with periods of exceptional activity on the sun (Chapman, 1957). This type of magnetic storm could be responsible for the very large injection of protons necessary to explain our observations. However, there is no quantitative theory which can be

used to correlate such an injection with the low latitude precipitation.*

Looking back over the past observations, the only increase of some significance in the inner zone of trapped protons was revealed by the measurements made by Filz and Holeman (1965) at low altitudes, of the 55 MeV trapped proton fluxes immediately following the "Starfish" high altitude nuclear explosion. Their observations were consistent with a simple 2° equatorial pitch-angle redistribution which moved particles down the field lines. Subsequent analysis by Cladis et al., (1970), while making this interpretation plausible has not yielded quantitative proof of this hypothesis. Although the observations here at $L = 1.90$ could be explained by a pitch angle redistribution caused by "Starfish", the necessary increase at $L = 1.20$ could not be accounted for by the same redistribution since this observation was made at the equator ($B/B_0 = 1.00$). To explain the order to magnitude increase at $L = 1.20$ would necessitate a redistribution in L and/or an acceleration mechanisms.

Further evidence for "Starfish" having caused the increase in the proton fluxes is the observation by Fischell et al., (1966) who reported that damage to solar cells of the 1961 $\alpha\eta$ 1 and 2 satellites following the nuclear explosion which could "not be explained by an omnidirectional fission-electron spectrum". These authors postulated "a significant increase in the number of protons with $E > 4.5$ MeV being redistributed at least to an altitude range between 400 and 1200 km" by "Starfish". Thus, if the 8-25 MeV protons were to have been introduced by "Starfish", it would provide a resolution to this long outstanding problem.

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*Note added in proof: The recent tropical aurora observed April 13, 14, 1981, coincided with very large solar flares, had a Dst ≃ -300γ (Joselyn, 1981; Sugiura, 1981).

Another curious aspect of the L=1.20 observations which must be explained by any source is the constancy of the flux from 1964 to 1968. A similar constancy in the 55 MeV proton fluxes was observed at lower altitude in the measurements of Filz and Holeman (1965), Filz (1967), and Heckman and Nakano (1969). These authors showed that this could result from a chance coincidence between the rapid flux decay following "Starfish" and the decreasing atmospheric density correlated to the approaching solar minimum. While the atmospheric density - solar cycle relationship is not well established at the higher altitudes considered here, it would seem to be a likely explanation for these present results at L = 1.20 as well.

In order to investigate the possibility that the 8-25 MeV protons reported here were present prior to "Starfish", a close examination of pre-"Starfish" data was made. Unfortunately, very little directional flux data was obtained prior to this artificial event, and geiger counter data cannot be used for quantitative comparisons. The NERV nuclear emulsion data (Naugle and Kniffen, 1961, 1963) would be the most reliable for determining proton fluxes in this energy interval, but there is some absolute flux uncertainty due to the spinning of the rocket. The NERV "point B" which corresponds to L = 1.72 and B = 0.198 (see Figure 11 in Naugle and Kniffen, 1963) is closest to our data point at L = 1.90 (B = 0.215). The proton energy spectra at the NERV "point B" when properly interpolated, would give 8 to 25 MeV proton fluxes in reasonable agreement with an extrapolation of our L = 1.90 data back to 1960. Naugle and Kniffen (1963) suggested that the main source of the upturn at the low energies in the proton spectra results

from the injection of the albedo neutrons by solar protons (SPAND).

The low energy protons observed at L = 1.72, B = .198 (NERV "point B") seems to disappear at L = 1.64, B = .196 ("point C"). These same authors interpret this observation as resulting from the transition from the SPAND source to the equatorially shadowed (from the polar cap) region where the CRAND source predominates. Our present data however, shows intense fluxes of low energy protons down to L = 1.35, a region in L-space which is inaccessible to SPAND.

For the SPAND process to contribute one would also have to assume that the major contribution came from the large solar flares which occurred during the 1950's and that the absence of large proton producing flares in the 1960's has led to the decay. The August 1972 flare was large enough but still probably less than 1/10th the size of the sum of the 1950's flares and hence would probably not contribute sufficient low energy protons to be observed because of the uncertainties of comparing different data sets.

Another possibility to explain these protons is that they could have been brought onto the lower L values by inward radial diffusion processes such as those proposed by Farley and Walt (1971). However, they should be present in the NERV data as well. Finally an alternative hypothesis is that the low L regions were populated with low energy protons by "Starfish" and that the high L regions were populated by the SPAND process. Thus, the NERV data does suggest a source of low energy protons, which if redistributed a few degrees in equatorial pitch angle by "Starfish", might account for the high fluxes at the lower L values reported by Bostrom et al., (1971).

CONCLUSION

Although we cannot completely explain the observed phenomenon, i.e., the steady decrease of the 8-25 MeV proton fluxes at $L \leq 1.9$ over the 13-years observation period, it is nevertheless well established from 5 independent sets of observations that the originally observed decay of the proton fluxes between 1964 and 1968, at $L = 1.35$ and 1.90 has continued unabated until at least August 1976.

This decrease in the fluxes which spans approximately 13 years, cannot be related to the 11-year solar cycle. Indeed, for the solar minima which occurred in ~1965 and ~1976, any solar-induced modulation of the proton fluxes would have resulted in comparable flux intensities at these 2 times.

There is no doubt, based on 3 independent sets of observations, that the flux at $L = 1.20$, which was observed to be constant up until 1969, started decaying at approximately that time with the shortest mean life observed in our data, i.e. 3.07 ± 0.25 years.

While it is possible that the 8-25 MeV protons that we are observing were originally introduced by some large magnetic storm in the 1950's, this explanation seems unlikely; most probably, we are simply looking at protons redistributed in L value and pitch angle by the "Starfish" high altitude nuclear explosion on July 9, 1962.

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TABLE I

Orbit Parameters of Air Force Satellites 72-1, S3-2 and S3-3

	72-1	S3-2	S3-3
Launch Date	10/02/72	12/03/75	07/08/76
Inclination (°)	98.4	96.3	97.5
Period (min)	91	96.3	176.6
Apogee (kms)	750	1558	7856
Perigee (kms)	729	236	246

TABLE II

Mirroring Proton Fluxes ($8 \le E_p \le 25$ MeV) at L = 1.20, 1.35, and 1.90
as Measured from January 1964 until August 1976 by
Satellites 1963-38C, DIAL, 72-1, S3-2, and S3-3

		Proton Fluxes, J (p/MeV-cm^2-sec-ster)					
		Jan 64	Jan 69	Apr 70	Jan 73	Feb 76	Aug 76
L = 1.20	$0.180 \le B \le 0.190$ $700 \le h_{min} \le 800$ $B/B_0 = 1.00$	28±2*	28±2*	21.5±2.5*	6.3±1.0	3.0±0.4	
L = 1.35	$0.170 \le B \le 0.180$ $800 \le h_{min} \le 900$ $1.31 \le B/B_0 \le 1.35$	206±14*	102±7*	95±10*		20.0±3.0	23.0±3.0
L = 1.90	$0.205 \le B \le 0.225$ $600 \le h_{min} \le 800$ $4.25 \le B/B_0 \le 5.35$	135±10*	42±3*		16.5±1.1	9.4±0.4	

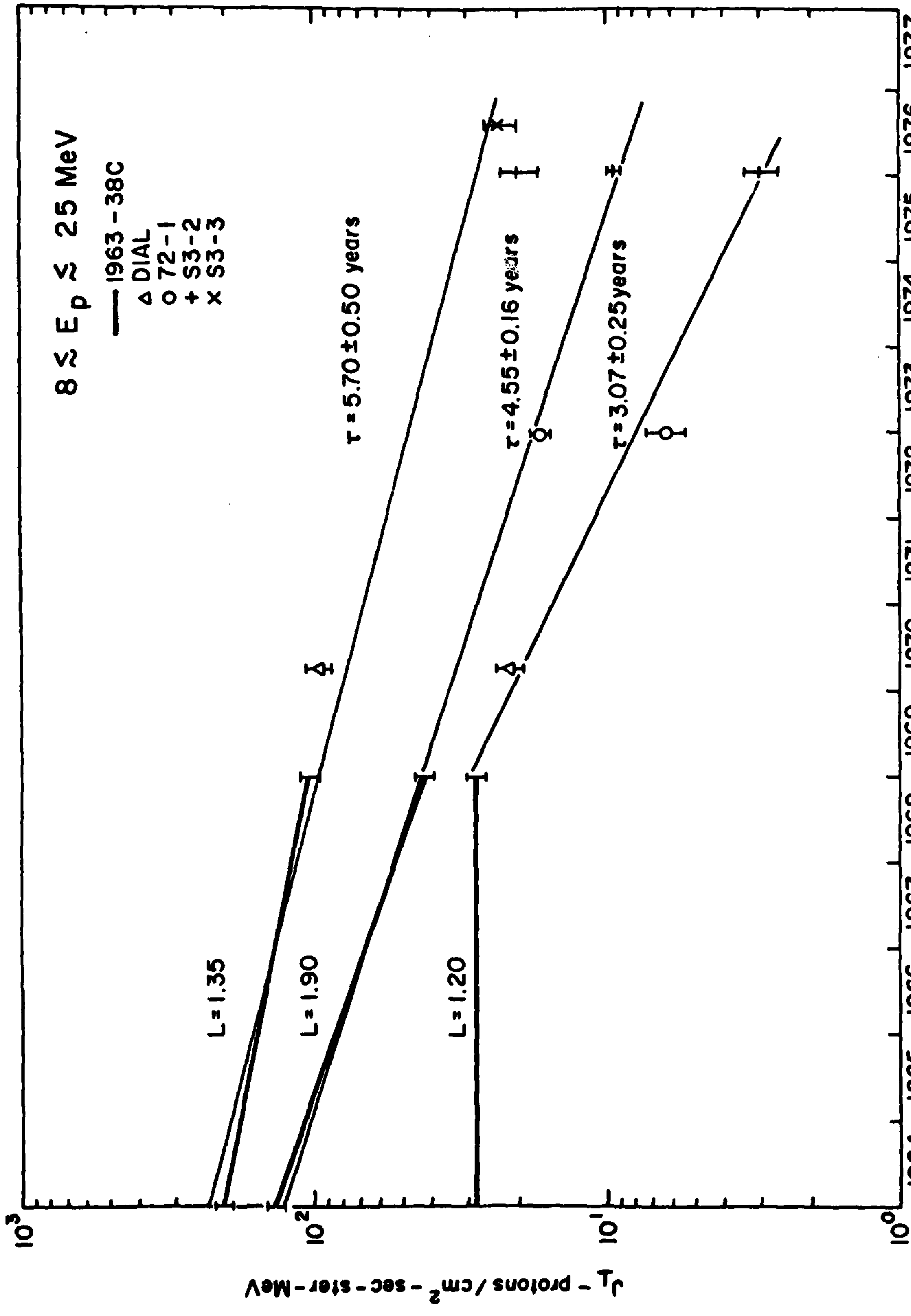
TABLE III

Mean Lives, τ (years) of the Proton Flux Decay
at L = 1.20, 1.35, and 1.90

L	1963-38C	Total Data
1.20	Const	3.07 ± 0.25
1.35	7.1 ± 1.4	5.70 ± 0.50
1.90	∿4.3 ± 0.4	4.55 ± 0.16

FIGURE CAPTIONS

Figure 1. Mirroring proton fluxes ($8 \leq Ep \leq 25$ MeV) as measured by satellites 1963-38C, DIAL, 72-1, S3-2, and S3-3, from January 1964 until August 1976.



8 ≲ E_p ≲ 25 MeV
— 1963-38C
Δ DIAL
o 72-1
+ S3-2
x S3-3
τ = 5.70 ± 0.50 years
τ = 4.55 ± 0.16 years
τ = 3.07 ± 0.25 years
L = 1.35
L = 1.90
L = 1.20
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
10^3
10^2
10^1
10^0
J_L - protons / cm^2 - sec - ster - MeV

Figure 1

REFERENCES

Bostrom, C.O., Beall, D.S., and Armstrong, J.C., "Time history of the inner radiation zone October 1963 to December 1968", Models of the Trapped Radiation Environment, Volume VII: Long Term Time Variations, NASA SP-3024, 25-35, 1971.

Cage, A.L., and Zawalick, E., "A discussion of the geomagnetic indices Kp and ap, 1932 to 1971", Report AFCRL-72-0693, November 1972.

Chapman, S., "The aurora in middle and low latitudes", Nature, 179, 7-11, 1957.

Cladis, J.B., Davidson, G.T., Francis, W.E., Jaggi, R.K., Nakano, G.H., and Ossakow, S.L., "Redistribution of trapped protons by Starfish nuclear explosion", J. Geophys. Res., 75, 57-68, 1970.

Farley, T.A., and Walt, M., "Source and loss processes of protons of the inner radiation belt", J. Geophys. Res., 76, 8223-8240, 1971.

Filz, R.C., and Holeman, E., "Time and altitude dependence of 55 MeV trapped protons, August 1961 to June 1964", J. Geophys. Res., 70, 5807-5822, 1965.

Filz, R.C., Katz, L., Sellers, B., Hanser, F.A., and Holeman, E., "Observations of 5-45 MeV protons at $L \leq 3$ and $L \geq 7$", Space Research XIV, 321-326, Berlin, 1974.

Fishell, R.E., Martin, J.H., Radford, W.E., and Allen, W.E., "Radiation damage to orbiting solar cells and transistors", 793-807 in Radiation Trapped in the Earth's Magnetic Field, B.M. McCormac, Editor, D. Reidel, Holland, 1966.

Fischer, H.M., Auschrat, V.W., and Wibberenz, G., "Angular distribution and energy spectra of protons of energy 5 ≤ E ≤ 50 MeV at the lower edge of the radiation belt in equatorial latitudes", J. Geophys. Res., 82, 537-547, 1977.

Heckman, H.H., and Nakano, G.H., "Low-altitude trapped protons during solar minimum period, 1962-1966", J. Geophys. Res., 74, 3575-3590, 1969.

Holeman, E., Davis, A.F., and Hagan, M.P., "Analysis of data from research satellites", Final Report, AFGL-TR-78-0187, July 1978.

Holeman, E., and Filz, R.C., "Proton flux data obtained on Air Force Satellite 72-1 over the period October 1972 - February 1973", Emmanuel College, Scientific Report No. 2, AFCRL-TR-75-0377, June 1975.

Holeman, E., Parsignault, D.R., Hagan, M.P., and Filz, R.C., "Proton fluxes (0.08-100 MeV) as measured by the Air Force Satellites S3-2 and S3-3", AFGL Report to be published.

Joselyn, J.C., Private communication, 1981.

Mayaud, P.N., and Romana, A., "Supplementary geomagnetic data 1957-1975", IAGA Bull. No. 39, 1977.

McIlwain, C.E., "Redistribution of trapped protons during a magnetic storm", Space Res. IV, 374, D.G. King-Hele, P. Muller and G. Pighini, Editors, North Holland Publishing Co., Amsterdam, 1965.

Morel, P.R., Hanser, F.A., and Sellers, B., "A satellite telescope for protons and alphas", Final Report, Panametrics, Inc., AFCRL-TR-74-0531, November, 1974.

Morel, P.R., and Sellers, B., "Design and fabrication of a heavy particle identification instrument for satellite", R&D Equipment Information Report, Panametrics, Inc. Contract F19628-69-C-0234, December 1972.

Naugle, J.E., and Kniffen, D.A., "Flux and energy spectra of protons in the inner Van Allen Belt", Phys. Rev. Letters, 7, 3, 1961.

Sugiura, M., Private communication, 1981.

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